Ultrasound Evaluation of the Normal Ulnar Nerve in Guyon's Tunnel: Cross-Sectional Area and Anthropometric Measurements

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Abstract

Introduction: Ulnar nerve entrapment is an infrequent disorder, but is often seen in long distance cycling. Electrodiagnosis and imaging modalities, including ultrasound, are employed for diagnosis. The goal of this study was to obtain sonographic normative data of the ulnar nerve (UN) in Guyon's tunnel, in order to establish the diagnosis of Guyon's tunnel syndrome in future studies. Anthropometric measures were also obtained.

Methods: 46 healthy volunteers (male=30) were recruited (age=24.7±3.1 years), and a total 83 wrists were examined. The examinations included anthropometric measurements (wrist width, depth, circumference, palm length and hand width) and ultrasound measurement of the cross-sectional area (CSA) of the UN in Guyon's tunnel. B-mode sonography and power Doppler were employed.

Results: The UN CSA in Guyon's tunnel for males was 6.0 ± 2.0 mm2, and 5.0 ± 1.0 mm2 for females. There was a significant difference between female and male in the measurements of wrist width, depth, circumference; palm length, width and UN CSA (p<.001). The UN CSA was correlated with wrist width, wrist depth, wrist circumference, palm length and hand width (p<0.01). Differences were noted within and between gender groups of UN CSA within Guyon's tunnel.

Conclusion: Nerve cross-sectional area may differ by gender and this may be related to body size. Therefore, the contralateral side is more useful as a reference standard than the gender mean.

Introduction

The annual incidence of upper extremity cumulative trauma disorders (CTD) ranges from 21.1 to 25.3% in industrial and clerical occupations [1, 2], and carpal tunnel syndrome and cubital tunnel syndrome are the two most common. The ulnar nerve (UN) entrapment at the Guyon's tunnel is far less frequent, estimated to be one-twentieth of that occurring at the cubital tunnel [3]. The exact prevalence of Guyon's tunnel syndrome is unknown due to limited existing studies. Despite the low prevalence among the general population, the prevalence of UN entrapment in the Guyon's tunnel, referred as "cyclist's palsy" or "handlebar palsy" seems to be relatively common among long distance cyclists. Paterrson et al reported that 36% of cyclists (n=25) experienced ulnar nerve symptoms after a long distance race [4]. Thus, although the prevalence of UN entrapment at Guyon's tunnel might be low in the general population, in certain groups where there is prolonged compression on the wrist, the prevalence may be higher.

The UN enters Guyon's tunnel after giving rise to dorsal cutaneous and palmar cutaneous branches. These two sensory branches to the hand do not enter Guyon's tunnel. The UN is apposed to the ulnar artery as it travels adjacent to the pisiform. The UN bifurcates into the superficial sensory branch and the deep motor branch distal to the pisiform but proximal to the hook of the hamate. The superficial sensory branch innervates the palmaris brevis muscle and is sensory for the ulnar surface of the hypothenar eminence and the ulnar half of the fourth and fifth digit. The superficial branch further bifurcates into digital nerves distal to the hamate hook to innervate the fourth and fifth fingers [5]. The deep motor branch supplies the hypothenar muscles, including the abductor and flexor digiti minimi. It then rotates about the hook of the hamate and deviates laterally across the palm to innervate the dorsal interossei, the third and fourth lumbricals, the adductor pollicis, the flexor pollicis brevis, and terminates in the first dorsal interosseous muscle [5,6].

Ultrasonography has been increasingly used to assess the peripheral nervous system (PNS) both morphologically and dynamically [7-11]. Morphological assessment of the PNS typically involves measurements of the nerve cross sectional area (CSA) [7, 9, 10, 12-14, 27]. Many reports have demonstrated correlations of enlarged nerve CSA and neuropathy documented both clinically and electrophysiologically [9, 12, 15-21). Additionally, enlarged CSA has been shown to correlate with clinical severity in patients with ulnar and median neuropathies [11]. There is a lack of sonographic diagnostic criteria for UN entrapment in the Guyon's tunnel. Gross and Gelberman described internal topography of Guyon's tunnel to simplify localization of lesions. Zone 1 corresponds to the entrance of the tunnel through to the bifurcation of the UN. Zone 2 is distal and medial from zone 1 and contains the motor branch. Zone 3 is radial to zone 2 and distal to zone 1; and contains the superficial sensory branch [5]. Recently, there was a reclassification based on clinicoanatomic presentation to include two additional zones, but it should be noted that zones 1-3 were largely unchanged [8].

The purpose of this study was to measure the CSA of the UN in zones 1, 2 and 3 of Guyon's tunnel and to test for correlations between the UN CSA and anthropometric measurements of the hand. In addition, we described presence and nature of the associated vascular structures within the tunnel of Guyon as evaluated with power Doppler imaging.

Materials and Methods

The study protocol was approved by the Institutional Review Board and informed written consent was obtained. Asymptomatic volunteers between the ages of 18 years and 65 years were recruited through a convenience sample of university students, staff, and faculty. Volunteers completed a questionnaire documenting general health, handedness, specific health conditions (peripheral neuropathy or demyelinating diseases, stroke, diabetes, malnutrition, hypothyroidism, rheumatoid arthritis and other rheumatoid or connective tissue diseases, osteoarthritis, or pregnancy), work and sport history, and present or past hand/wrist injury status. Exclusion criteria included any upper extremity symptoms within the past 6 months, previous or present hand or wrist injury or surgery, specific health conditions such as peripheral neuropathy, demyelinating disease, stroke, diabetes, malnutrition, hypothyroidism, rheumatoid arthritis, connective tissue disease, pregnancy, and severe cardiovascular and/or respiratory diseases. Ultrasound measures and anthropometric data were collected, on one or both wrists, from 46 volunteers (16 female; mean age 24.7 3.1 years) for a total of 83 wrists. Nine wrists were excluded (4 due to prior fracture and/or surgery, 2 due to prior sprain without surgery, and 3 due to recent paresthesia within the UN distribution in the hand). There were 41 dominant wrists and 42 nondominant wrists.

Anthropometric measurements of the wrist and hand were obtained using digital calipers (UltraTech, General Tools and Instruments, New York, NY, USA) and measuring tape by an examiner blinded to the ultrasound nerve CSA measurements. The anthropometric measurements (Figure 1) included wrist width (distance between the outer borders of radial and ulnar styloid processes), wrist depth (volar to dorsal distance at distal wrist crease), wrist circumference (at distal wrist crease), hand width (distance between second and fifth metacarpal heads), and palm length (middle point of distal wrist crease to middle point of third metacarpophalangeal joint).

Gray-scale sonography examinations were performed using an L8-18i transducer (GE LOGIQ E9 sonographic system; GE Healthcare, Milwaukee, WI, USA) by a boardcertified chiropractic radiologist with 3 years' experience in musculoskeletal sonography. All scans were performed on the volar aspect of the wrist with the volunteer seated and their forearm/wrist resting comfortably in full supination on an examination table. The flexor carpi ulnaris tendon was identified at the volar wrist crease as an initial external reference point. The bony acoustical landmarks of the pisiform and the hook of the hamate were used as internal reference points during scanning. A liberal amount of coupling gel was applied to the volar hand and wrist. Cine loop images of the UN were acquired in the transverse plane approaching the pisiform through the distal bifurcation. The CSA of the UN was acquired at the level of the pisiform, using the echogenic cortex of the pisiform as a reproducible landmark (Figure 2A). The probe was then maneuvered distally, keeping the UN in cross-section, until the nerve divided into the distal motor and sensory branches. At this point, the CSA was measured in the transverse plane (Figure 2B). Intraneural hyperemia was assessed using power Doppler in the transverse plane with the pisiform in the field of view. The CSA of the UN was measured using the ellipsoid and/or tracing functions on the GE LOGIQ E9. The margin of the nerve was defined as the area deep to the hyperechoic nerve sheaths. The shape of the nerve dictated which measurement function to use. A round or oval nerve dictated the use of the ellipsoid function, whereas an irregular-shaped nerve dictated the use of the tracing function.

The interexaminer reliability for measuring the CSA of the UN at the three sites was assessed between the primary investigator and two other chiropractic radiologists with 4 years and 7 years of experience in musculoskeletal sonography. Volunteers were selected for interexaminer reliability assessment using a random number generator. Each examiner measured the CSA of the UN on static images that were previously obtained as cine loops. Interexaminer and intraexaminer reliability analyses were performed using the intraclass correlation coefficient with IBM SPSS 18 software (IBM Corporation, Armonk, NY, USA) using a two-way random effects model. Mean and standard deviation were analyzed on the collected CSA data. A t test was used for comparing gender (independent samples) and handedness (paired samples) groups between UN CSA and anthropometric variables. Pearson correlation was used to analyze association between nerve CSA and anthropometric variables.

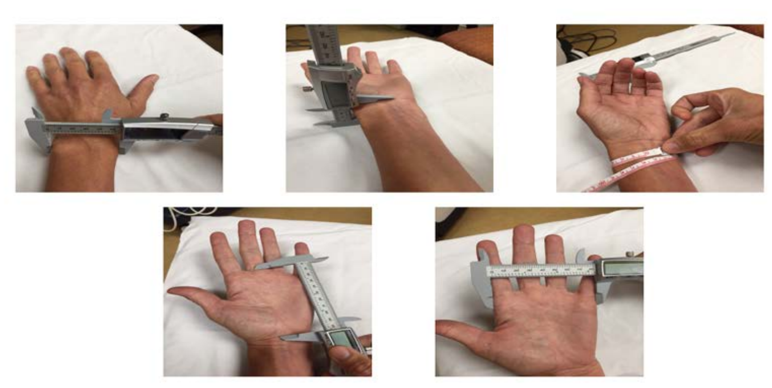

Figure 1 Photographs of the individual anthropometric measurements of the wrist. (A) Wrist width, (B) wrist depth, (C) wrist circumference, (D) hand width, and (E) palm length.

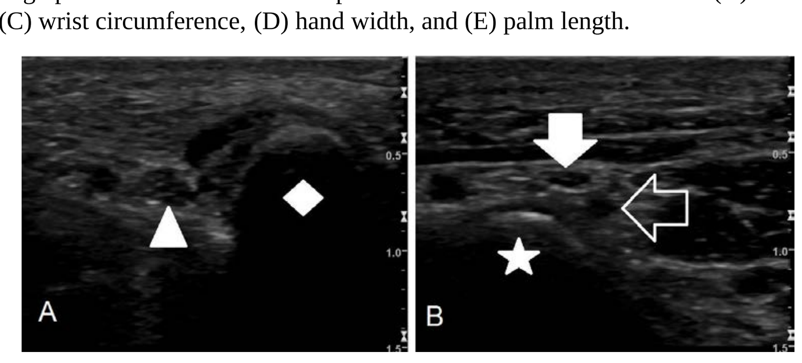

Figure 2 (A, B) Transverse high-resolution ultrasound image of the ulnar nerve within Guyon's tunnel in (A) Zone 1 and (B) Zones 2 and 3. The fascicular pattern of the ulnar nerve (solid white arrowhead in A) can be discerned adjacent to the pisiform (solid white diamond in A). In B, the superficial sensory branch can be seen (solid white arrow), and the deep motor branch (open arrow) begins to reflect around the hook of the hamate (solid white star).

Results

The UN was identified in 100% of subjects within Guyon's tunnel. Descriptive statistics and t-test results are reported in Table 1. The mean cross sectional area of the UN in Guyon's tunnel was 6.0 +/- 2.0 mm2 in males and 5.0 +/- 1.0 mm2 in females. The cross sectional area of the motor branch of the UN was 2.0 +/- 1.0 mm2 in males and 2.0 +/- 1.0 mm2 in females. The cross sectional area of the sensory branch of the UN was 3.0 +/- 1.0 mm2 in males and 3.0 +/- 1.0 mm2 in females. Intraneural hyperemia was not present in any subject. Analysis of the distal branches was excluded in 10 wrists for the following reasons: In one subject, the distal branches of the UN could not be confidently identified due to poor image resolution. In four wrists, the motor branch was not identified, likely a combination of the small size of the nerve and its undulating course. In three cases, cine loops were missing on the distal branches and only static images were available. In two wrists, there was a trifurcation of the distal branches simultaneously. There was a significant difference between females and males in the measurements of wrist width, wrist depth, wrist circumference, palm length, hand width and UN CSA at the level of the pisiform (p<0.001) (Table 1). There was no significant difference between dominant and non-dominant hands in the measurements of wrist width, wrist depth, wrist circumference, palm length, hand width and UN cross-sectional area (p>0.05). Pearson's r coefficient for correlation between right and left UN CSA was 0.656 (significant at .001 level (2-tailed)). There was significant correlation between nerve size and all anthropometric variables and the correlation coefficients are displayed in Table 2. Age and nerve CSA was not significant (Pearson's r =0.115; p=.304). Inter- and intraexaminer reliability of the CSA measurements of the UN between three examiners was very good (Table 3).

Table 1 The *t* test of anthropometric and sonographic measurements between male and female volunteers.

	Gender	*N*	Mean (mm)	Standard deviation (mm)	*t*	*df*	*p*	Mean difference (mm)
Wrist width	M	51	60.1	4.3	10.43	79.9	<0.001	7.9
	F	31	52.3	2.6				
Wrist depth	M	51	43.0	3.7	6.56	80.0	<0.001	5.3
	F	31	37.7	3.3				
Wrist circumference	M	51	174.3	11.7	11.55	79.8	<0.001	23.6
	F	31	150.7	6.7				
Palm length	M	51	109.8	5.9	7.16	80.0	<0.001	9.0
	F	31	100.9	4.7				
Hand width	M	51	86.1	5.8	8.57	80.0	<0.001	10.3
	F	31	75.9	4.2				
UN CSA	M	51	6.0 mm^2	2.0 mm^2	4.26	80.0	<0.001	1.0 mm^2
	F	31	5.0 mm^2	1.0 mm^2				

CSA = cross-sectional area; F = female; M = male; UN = ulnar nerve.

Table 2 Correlation matrix for anthropometric variables and UN CSA.

	Wrist width	Wrist depth	Wrist circumference	Palm length	Hand width	Age	UN CSA
Wrist width							
Wrist depth	0.814 *						
Wrist circumference	0.943 *	0.836 *					
Palm length	0.700 *	0.607 *	0.739 *				
Hand width	0.761 *	0.805 *	0.764 *	0.718 *			
Age	0.126	0.116	0.201	0.301	0.215 **		
UN CSA	0.574 *	0.438 *	0.573 *	0.448 *	0.464 *	0.115	

* Correlation is significant at the 0.01 level (two tailed).
** Correlation is significant at the 0.05 level (two tailed).
CSA = cross-sectional area; UN = ulnar nerve.

Table 3 Reliability analysis.[a]

	ICC	95% CI
Interexaminer		
Examiner 1 versus 2	0.867	0.573–0.866
Examiner 1 versus 3	0.895	0.832–0.934
Examiner 2 versus 3	0.890	0.801–0.936
Intraexaminer		
Examiner 1	0.911	0.858–0.945

95% CI = 95% confidence interval; ICC = intraclass correlation coefficient.
[a] Measures analyzed as a two-way random model with absolute agreement.

Discussion

The mean nerve CSA for the UN in our study was slightly different from that reported by others. Yalcin et al examined healthy wrists from 72 volunteers of Turkish descent (36 male, 36 female) and reported a mean of 4.9±0.6 mm2 while Tagliafico et al examined 40 volunteers (20 male, 20 female) and reported 3.1±1.0 mm2 [13,14]. Bathala et al reported a mean CSA of 3.6 +/- 0.5 mm2 in 100 healthy Asian subjects [9]. Our mean CSA was larger (gender combined, 5.8±1.7 mm2) which could be explained by the gender bias in our study (56 male, 31 female) as nerve CSA is dependent on gender [10,14]. Additionally, morphometric differences may exist between ethnic populations. This presents challenges for establishing universally applicable reference data for normal CSA of UN in Guyon's tunnel. However, since there was no significant difference between the dominant and non-dominant hands, it is more practical to compare the symptomatic hand with the asymptomatic hand of the same patient in order to make a conclusion of ulnar nerve enlargement. Multiple studies have validated the internal consistency of asymptomatic of nerve CSA [13,14] and our findings are similar. The diagnosis of ulnar neuropathy should still be based upon clinical findings in adjunction with other diagnostic procedures.

In two wrists, the UN divided into three branches upon the exit from zone 1. Specifically, the superficial sensory branch of the UN bifurcated simultaneously as the single deep motor branch veered off into its normal direction. This morphology has been reported [22]. We excluded these morphological types from analysis of the distal branch UN CSA due to the difficulty of measurement and the likelihood of a confound.

There was a significant correlation between all five anthropometric variables (wrist width, wrist depth, wrist circumference, palm length, hand width) and UN CSA (p<0.01). Previous studies have identified significant correlation with other anthropometric variables such as body height and weight [14]. There is conflicting data on the correlation between nerve CSA and BMI; correlation with body weight has been more consistent [10, 23, 24, 26, 27]. There was no correlation between age and UN cross-sectional area (p=0.304) likely due to the composition of our convenience sample (mean age 24.7 +/-3.1) (Table 2). While there was significant correlation between anthropometric variables and UN CSA, no relationship was of greater significance than that between right and left UN CSA. Thus, it seems that the best internal control for nerve CSA is the contralateral nerve.

The reliability criteria described by Dawson and Trapp outlines ICC's 0.41-0.60 as fair, 0.61-0.80 as good, 0.81-0.92 as very good and 0.93-1.00 as excellent agreement [25]. Our agreement for measuring the cross sectional area of the UN in Guyon's tunnel and distal branches was very good (Table 3). A recent study by Tagliafico et al assessed the cross sectional area of the UN within Guyon's tunnel and determined a slightly smaller mean cross sectional area (3.1 +/- 1.0 mm2) than our results [13]. We determined that the cross sectional area of the UN does depend on some anthropometric characteristics and it is possible that morphometric differences existed between our patient populations. Our results were in agreement with their findings on the lack of correlation between nerve size, age and dominant handedness [13]. We did not assess for correlations between height and nerve size.

There are several limitations in our study design. The subjects were recruited from a university setting, the population of which consists primarily of young healthy Caucasian males. Thus our sample was not representative of the general population. This may partially explain the finding that age did not correlate with the CSA of UN, which was inconsistent with the findings of others [9]. Although there is a gender bias in our study, the findings of a significant difference of UN CSA between males and females is congruent with previous work [10].

Conclusion

UN cross-sectional area at Guyon's tunnel at the level of the pisiform was 6.0 ± 2.0 mm2 for males and 5.0 ± 1.0 mm2 for females. The differences in gender, body type and wrist/hand size should be considered when establishing a reference or normal value for the UN CSA in the Guyon's tunnel. Further investigation comparing electrodiagnostically confirmed UN neuropathy with healthy controls would provide quantitative reference for sonographic diagnosis of UN entrapment in Guyon's tunnel.

References

1. Gerr F, Marcus M, Ensor C et al. A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. Am. J. Ind. Med. 2002, 41 (4): 221-235.
2. Werner RA, Franzblau A, Gell N et al. A longitudinal study of industrial and clerical worker: predictors of upper extremity tendonitis. J. Occup. Rehabil. 2005, 15 (1):37–46.
3. Elhassan B, Steinmann S. Entrapment neuropathy of the ulnar nerve. J Am Acad Orthop Surg. 2007, 15(11):672–681.
4. Patterson JMM, Jaggars MM, Boyer MI. Ulnar and median nerve palsy in long distance cyclist: a prospective study. The American Journal of Sports Medicine. 2003. 31(4): 585-589.
5. Gross MS, Gelberman RH. The anatomy of the distal ulnar tunnel. Clinical Orthopaedics and Related Research. No. 196; June 1985.
6. Sallomi D, Janzen DL, Munk PL et al. Muscle denervation patterns in upper limb nerve injuries: MR imaging findings and anatomic basis. Am J Roentgenol. 1998;171:779–784.
7. Jacob D, Creteur V, Courthaliac C et al. Sonoanatomy of the ulnar nerve in the cubital tunnel: a multicentre study by the GEL. Eur Radiol. 2004, 14(10):1770-3.
8. Erkin G, Uysal H, Keles I et al .Acute ulnar neuropathy at the wrist: a case report and review of the literature. Rheumatol Int. 2006, 27(2):191–196.
9. Bathala L, Kumar P, Kumar K et al. Ultrasonographic cross-sectional area normal values of the ulnar nerve along its course in the arm with electrophysiological correlations in 100 Asian subjects. Muscle Nerve. 2012 Oct 2.
10. Cartwright MS, Shin HW, Passmore LV et al. Ultrasonographic findings of the normal ulnar nerve in adults. Arch Phys Med Rehabil. 2007 Mar;88(3):394-6.
11. Lee D, van Holsbeeck MT, Janevski PK et al. Diagnosis of carpal tunnel syndrome: ultrasound versus electromyography. Radiol Clin North Am 1999; 37:859–872.
12. Hooper DR, Lawson W, Smith L et al. Sonographic features in hereditary neuropathy with liability to pressure palsies. Muscle Nerve. 2011; 44(6): 862-7.
13. Tagliafico A, Martinoli C. Reliability of side-to-side sonographic cross-sectional area measurements of upper extremity nerves in healthy volunteers. J Ultrasound Med 2013; 32:457-462.
14. Yalcin E, Onder B, Akyuz M. Ulnar nerve measurements in healthy individuals to obtain reference values. Rheumatol Int. 2012 Sep 5.
15. Ayromlou H, Tarzamni MK, Daghighi MH et al. Diagnostic value of ultrasonography and magnetic resonance imaging in ulnar neuropathy at the elbow. ISRN Neurol. 2012:491892.
16. Miller TT, Reinus WR. Nerve entrapment syndromes of the elbow, forearm and wrist. AJR 2010;195:585-594
17. Tai TW, Wu CY, Su FC et al. Ultrasonography for diagnosing carpal tunnel syndrome: a meta-analysis of diagnostic test accuracy. Ultrasound Med Biol. 2012 Jul;38(7):1121-8.
18. Scheidl E, Böhm J, Simó M et al. Ultrasonography of MADSAM neuropathy: focal nerve enlargements at sites of existing and resolved conduction blocks. Neuromuscul Disord. 2012 Jul;22(7):627-31.
19. Kara M, Özçakar L, Tiftik T et al. Sonographic Evaluation of sciatic nerves in patients with unilateral sciatica. Arch Phys Med Rehabil Vol. 2012 Sep;93(9):1598-602.
20. Ginanneschi F, Filippou G, Milani P et al. Ulnar nerve compression neuropathy at Guyon's canal caused by crutch walking: Case report with ultrasonographic nerve imaging. Arch Phys Med Rehabil 2009;90:522-4.
21. Yoon SJ, Walker FO, Cartwright MS. Ulnar nerve and cubital tunnel ultrasound in ulnar neuropathy at the elbow. Arch Phys Med Rehabil 2008, 89:997-889.
22. Nitsu M, Kokubo N, Nojima S. Variations of the ulnar nerve in Guyon's Canal: In vivo demonstration using ultrasound and 3T MRI. Acta Radiologica 2010 (8).
23. Peeters EY, Nieboer KH, Osteaux MM. Sonography of the normalulnar nerve at Guyon's canal and of the common peroneal nerve dorsal to the fibular head. J Clin Ultrasound2004;32:375–380.
24. Werner RA, Jacobson JA, Jamadar DA. Influence of body mass index on median nerve function, carpal canal pressure, and cross-sectional area of the median nerve. *Muscle Nerve* **30:** 481–485, 2004.
25. Dawson B, Trapp RG. Basic and Clinical Biostatistics. 3rd ed. New York: Lange Medical Books/McGraw Hill; 2001.
26. Sugimoto T, Ochi K, Hosomi N et al. Ultrasonographic reference sizes of the median and ulnar nerves and the cervical nerve roots in healthy Japanese adults. Ultrasound Med Biol. 2013 Sep;39(9):1560-70. Epub 2013 Jul 3.
27. Chen J, Wu S, Ren J. Ultrasonographic reference values for assessing normal radial nerve ultrasonography in the normal population. Neural Regen Res. Oct 15, 2014; 9(20): 1844-9